THE ECONOMICS OF MACHINERY CHOICE IN CORN PRODUCTION

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The Economics of Machinery Choice in Corn Production

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TECHNOLOGICAL DEVELOPMENTS in all phases of corn production are occurring rapidly. Some of those having the greatest economic implication to farmers, as well as to machinery manufacturers and grain marketing firms, are the changes requiring new investment in production machinery. Farmers continually seek ways to increase their profit in the highly competitive corn production business. Therefore, they investigate alternative methods of production and their associated costs and returns. As more techniques requiring larger capital outlays are developed over a shorter time span, rational economic choice among the various alternatives becomes more difficult.[13*]

Two recent technological developments — field shelling of corn and narrow-row culture — have increased the alternative choices open to producers. Also, the continuing increase in size of field equipment adds to the available choices that need to be considered when a new farmer begins farming or when an established farmer makes a change from one production method to a different method.

Because of the necessary compatibility of row width and machine size among all machines in the corn production process, production machinery from planting through harvesting should be considered as a full complement or required set. More consideration than in the past needs to be given to production flow or to putting together a machine complement that provides for the highest overall net return for a particular size of farming operation.

Although harvesting of shelled corn in the field was developed and came into use at least 15 years ago, field shelling was almost insignificant as recently as 1956 when 96 percent of the corn acreage for grain in Illinois was harvested by mechanical corn picker. Even in 1960, 80 percent of the corn acreage for grain was harvested by corn picker. However, in 1966 less than half (43 percent) of the corn was harvested by corn picker, and 85.1 percent of the corn harvested as shelled corn was combined.[a] The harvesting trend is clear. It is only a matter of time until corn pickers are phased out as a harvesting tool, and the harvesting job is taken over by the combine. Many farmers are likely to trade their corn pickers before they are worn out and to get combines as soon as it is economically feasible. Some farmers with smaller corn acreage are likely to change harvesting methods only when their present corn pickers are worn out.

*** Superior numbers identify references in the bibliography on p. 23.**

[a] Illinois Cooperative Crop Reporting Service. Illinois Agricultural Statistics. Harvesting, Handling, and Drying Methods. Bulletin 67-2, p. 1. February, 1967.

However, it is unlikely that many corn pickers in the central part of the Corn Belt will be replaced by new corn pickers. Thus it appears that the combine, because of its high proportion of investment in the production machinery complement, will be the important factor determining the make-up of the whole machinery system.

REASONS FOR CHANGING MACHINERY COMPLEMENTS

Gross returns in the form of total yield and corn harvested are an important consideration in selecting a machinery complement, because when returns vary it is the difference between costs and returns, and not costs alone, that determines the optimum choice.

However, the variation of yield and corn harvested in experimental data is large, and this also varies from farm to farm as well as by cultural methods. The lease arrangements in division of costs and returns on rented land also vary. Therefore, it is better that each individual estimate his own gross return, depending on the variation in situations, and compare it with the relative costs of different corn production machinery complements.

At lower levels of output or with certain divisions of costs and returns on rented farms, it may be more efficient for the farm operator to hire part of the corn production process or rent some part of the required machinery complement rather than to own the full machinery set and do the work himself.

Narrow-Row Culture

Most of the recent pressure to change to narrow-row culture has been based on the expectation of increased yield. Increased costs are associated with narrow-row culture, but it has been hypothesized that yields will be increased sufficiently with narrow-row culture to more than offset the increase in cost.

Certain biological factors favor narrow-row culture. Equidistant plant spacing theoretically should give equal plant response to available water and nutrient supply. Narrow rows allow earlier shading of the ground which reduces weed control problems and reduces soil-moisture evaporation.[17] Narrow rows also allow for more equal distribution of sunlight to the plants.

Greater shading of the ground is the natural consequence of greater leaf exposure to the sun. Greater photosynthetic exposure should result in higher yields. Recent experiments do not show as much increase for narrow rows as might be expected, because it appears the top four or five leaves of the plant (which would be exposed to the sun in any case) are by far the most important in photosynthesis.[8, 14] Modification of leaf structure by plant breeding may improve the efficiency of lower leaves. However, modification of the number and size of ears per plant seems to be one of the most promising possibilities to increase grain yield.[14]

Most experiments show a wide range in the increase in both corn and soybeans because of narrow rows. The average yield increase for corn seems to be about 5 percent and about 10 percent for soybeans.[9] It is feasible that row spacing less than 30 inches may be optimum, but few experiments have been conducted yet that indicate any substantial advantage of smaller row width. Therefore, the analysis presented here will be confined to consideration of 38- to 40-inch and 30-inch row widths.

Changing Size of Machines

One of the major reasons for changing machinery always has been and likely will continue to be the development and manufacture of larger machines. These larger machines handle more rows or cover more width as they move across the field. With a relatively high labor cost and abundance of capital, capital investment is being substituted for labor. To get a larger labor return, farm operators are enlarging farm size.[12, 15] To operate larger farms with a minimal increase in labor, farm operators trade in their present equipment for larger equipment. There are discontinuities in both machine size and farm size. Thus the optimum size of machinery for a particular size of farm becomes an important economic consideration in making a choice among the various available machinery complements. The machinery cost curve does not decline monotonically with all changes from one farm size group to the next size group.[a] This increase in cost likely is caused by discontinuities in matching machine size to farm size. The larger farm size is too large for the machinery size complement that is optimum for the smaller size farm, but the next larger machinery-size complement is too large for the next larger size farm. The information presented here will help indicate the optimum acreage size for different machinery-size complements.

Of course, another reason for getting new machinery is to replace old machinery that is worn out. With the relatively rapid change in technological developments, a farm operator likely could not replace an old machine with a new machine similar in all respects to the old machine even if he wanted to. The old-style machines just aren't made anymore. Therefore the farm operator whose corn production machinery is worn out is automatically forced to make a decision about the alternative corn

[a] On cash-grain farms with soil ratings of 76 to 100, there is a per-acre increase in total machinery cost in going from the 340- to 499-acre group to the 500- to 649-acre group, and on cash-grain farms with soil ratings of 56 to 75, a machine cost increase occurs from the 260- to 339-acre group to the 340- to 499-acre group.[7]

production techniques available and the associated machinery complement required to apply these techniques.

Some farm operators who have acreage too small to justify ownership of a complete machinery complement may turn to machinery leasing of certain elements of the machinery complement — such as the combine — in order to continue profitable corn production. Still others who may have an even smaller corn or corn and soybean acreage may find it more profitable to hire certain parts of the farming operation — such as harvesting — when their present machinery is worn out.

Within this context, it seems clear that essentially all of the corn harvested for grain in Illinois eventually will be combined. Although there has been a very rapid increase in the amount of corn combined in Illinois in the last five years, the rate of change to combining in the next five years is likely to be less spectacular, depending to a greater degree on the attrition rate of existing corn pickers.

The cost curves presented here will give a better indication of the level of production required before ownership of certain elements of the machinery complement are feasible. This will indicate the ranges of production where alternatives other than machinery ownership should be considered.

OBJECTIVES

Because of the harvesting trend, the assumption is made that combining will be the major method of harvesting; and in this study only machinery complements including combines as the harvesting tool will be considered. Choice must be made between both conventional- and narrow-row equipment and among the various sizes of equipment to select an optimal machinery complement.[a]

The more specific objectives of the study are:

(1) To determine the best size of machines in the machinery complement for different levels of conventional-row corn production.

(2) To determine the best size of machines in the machinery complement for different levels of narrow-row corn production.

(3) To estimate the additional costs encountered with narrow-row production and compare total costs of narrow-row with wide-row equipment.

(4) To develop a simplified procedure, based on economic theory, to use in deciding when to trade machinery.

Costs are investigated for various sizes of machinery and for both conventional and narrow rows and are related to output. Costs could be

[a] For purposes of this study, conventional equipment is defined as that used with 38- to 40-inch-wide rows and narrow-row equipment is defined as that used with 30-inch-wide rows.

related to bushels of corn produced as the measure of output. However, since it is more conventional in the thinking of farmers and in farm management work to relate machinery cost to acres, the number of acres of corn produced will be used as the measure of output. The range in corn-acreage sizes considered will be from 100 to 700 acres. Given the cost-curve relationships and the physical limitation on acreage coverage by the various machines, it appears that machinery complement duplication would be necessary above 700 acres of corn or that much corn and some soybeans.

PROCEDURES

Ordinary budgeting techniques are used in this study to develop the cost curves for several machinery complements, both conventional and narrow row. These cost curves will be derived by using a large number of cost points calculated over the full relevant range of production. This procedure is similar to a recent study comparing wide row with narrow row at two points, 200-acre and 400-acre units.[9]

The cost curves presented will include both fixed and variable costs. The fixed costs will include depreciation, interest on investment, taxes, insurance, and shelter. The annual amount of these items is frequently calculated as a fraction of the original purchase cost of the equipment.[10] It is assumed that this fraction will be the same between conventional- and narrow-row equipment. From a practical standpoint in budgeting these various costs, the real problem is to obtain a realistic average purchase price for the various machinery complements. The National Farm Tractor and Implement Blue Book, which gives manufacturers' suggested list prices, was used as a general guide for pricing new equipment. However, observation of costs reported in farmers' record books indicates that bargaining between farmer and machinery dealer results in prices paid for machinery that are lower than the suggested retail price. Therefore, a number of the large-volume machinery dealers were interviewed to obtain their pricing suggestions. From these sources of information, price figures for use in this study were developed and we believe they are representative of those farmers face when they buy machinery. Costs of financing are not considered. Also, the per-acre cost figures are average annual figures taken over the life of the machine. Length of estimated machine life can have considerable effect on per-acre costs. However, so long as length of machine life is kept reasonable and comparable between machines, as is attempted in this study, comparison between machine complements will remain valid.

The cost relationships budgeted in the following analysis also assume the full cost of new machinery without any benefit of trade-in. Although the cash paid will be less, the new machine total value should not differ just because there is a trade-in involved. Thus the cost curves presented should still be valid guides for comparison between machine complements even though machinery is traded in. This does not answer, however, the question about when to trade. This question will be considered in a following section of this study.

Variable costs included in the analysis are labor, repairs, fuel, oil, and grease. Other input costs unrelated to machinery costs, such as insecticides, herbicides, fertilizer, and seed, will be held constant through various machine sizes. The marginal cost of these inputs in going from wide row to narrow row will be indicated. These marginal costs, however, should be offset by the marginal gains attributable to these inputs.

All costs will be shown on a per-acre basis at the various acreage levels of output. Budgeting analysis as used in this study has at least one weakness: the figures used in the budgeting procedure may not be substituted directly to a particular farm. However, even though the exact amounts of costs used in the following analysis may not be the same as those faced by some farmers, the cost relationship (between different machinery complements for different acreage levels with respect to both row width and machine size) should be valid and provide important guidelines for farmer decisions.

Initial Machine Costs

Prices used for figuring fixed costs of various machinery complements are given in Table 1. These are the best available estimates of total cost of the machines listed. They were taken from several sources and are for machinery that is equipped in the way most farmers are buying the machinery items. Planters are priced fully equipped with fertilizer, herbicide, and insecticide attachments. The cultivators priced are rear mounted since most farmers are now buying the rear-mounted cultivator, especially with narrow-row culture. Grain platforms and corn heads are listed separately, because on a farm where only corn is produced the grain platform need not be included as part of the capital cost. Machinery companies sell 4-row corn heads for the 85-horsepower combine, but some operators feel this may be a slight overload in heavy corn. However, with the 3-row head this combine is satisfactory.

The depreciation rate used on planters and cultivators is straight line for ten years with a 10-percent salvage value. Thus, 9 percent of the estimated purchase price is used as annual depreciation. It is assumed that combines have a useful life of seven years with a 12½-percent salvage value. Thus, 12½ percent of the estimated purchase price is used as annual depreciation for combines.

Table 1. — Purchase Price Estimates for Machinery

Planters (with fertilizer, herbicide, and insecticide attachments)	Conventional row	Narrow row
4-row	$1,200	$1,200
6-row	2,000	1,600
8-row	2,800	2,475
Cultivators (rear mounted)		
4-row	800	635
6-row	1,280	865
8-row	1,600	1,120

Self-propelled combines			Corn heads (rows and widths)					
	Without front	*Platform*	*Two 40"*	*Three 40"*	*Three 30"*	*Four 40"*	*Four 30"*	*Six 30"*
70 hp.	$ 7,230	$1,050 for 10 ft.	1,890		3,200			
85 hp.	8,725	1,300 for 13 ft.		3,400	3,360	4,112	4,032	
105 hp.	10,394	1,600 for 16 ft.				4,144	4,272	5,040

Tractor, 65 d.b. hp. — $5,800

Interest charge on capital is figured as 6 percent on the average machinery investment. Average investment is determined as follows:

$$(1) \qquad A = S + \frac{P - S}{2} = \frac{P + S}{2};$$

where: A = average investment,
P = purchase cost, and
S = salvage value.

A higher interest rate would be appropriate where machinery is purchased on consumer-credit loans on some farms. There is also good argument for a higher rate of interest to cover the risk cost of innovations causing faster obsolescence of machinery than has been estimated by the rate of depreciation used in this study. However, the relatively conservative 6-percent rate for well-secured loans is used in the following analysis.

Personal property taxes are estimated as 1 percent of purchase cost. Shelter costs, which should include a proportionate share of the farm shop, are estimated as 1 percent of purchase cost, and insurance is estimated as ¼ percent of purchase cost.

Machine Capacity

Fuel consumption is usually given on an hourly basis for various sizes of machines. Labor and other variable costs also are estimated on an hourly basis. Both capacity of the machine per hour and total seasonal capacity for the various machines must be determined. The following formula is used to determine the acres of work performed per hour:

$$(2) \qquad (WRVE)/8.25;$$

where: W = the width of the row in feet,
R = the number of rows of the machine,
V = the velocity of the machine in miles per hour, and
E = the field efficiency ratio of the machine.

Planting, cultivating, and combining velocities used are 4, 3, and 2.75 miles per hour respectively. Field efficiency is the ratio of the actual capacity to theoretical capacity. This efficiency ratio varies with the size of the field, amount of turning required, stopping for adjustment, unused width, and refilling and emptying of equipment. Thus actual capacity is always less than the theoretical capacity. Planting efficiency was estimated at 75 percent, cultivating efficiency at 80 percent, and combining efficiency at 70 percent.[3] Variable costs per acre for labor, fuel, repairs, oil, and grease are calculated from the acreage of work performed per machine-hour and hourly estimates of variable costs. Since some overhead labor is required, labor for planting was estimated at 116 percent of machine hours, 104 percent for cultivating, and 111 percent for combining.[2] Using ten-hour days and assuming a given number of days for the season for each field operation, the seasonal capacities for each machine were determined. These results are given in Tables 2 and 3.

Table 2. — Planting and Cultivating Capacities in Acres

Row size	Planting capacity[a]			Cultivating capacity[b]		
	Per machine hour	Per season for corn	Per season for beans	Per machine hour	Per season for corn	Per season for beans
4–30 in..........	3.64	328.7	236.6	2.91	426.9	351.5
4–40 in..........	4.85	437.9	271.1	3.88	569.2	468.7
6–30 in..........	5.45	492.5	304.9	4.36	641.1	527.9
6–40 in..........	7.27	656.3	406.3	5.82	855.3	704.3
8–30 in..........	7.27	656.3	406.3	5.82	855.3	704.3
8–40 in..........	9.70	875.7	542.1	7.76	1,139.9	938.7

[a] To determine season capacity it was assumed the optimum time to plant corn was May 6 to 22, with 10.5 good work days available during that period. Planting dates of May 24 to June 3 were assumed optimum for soybeans, with 6.5 good work days available during that period.[16, 4]

[b] To determine cultivating capacity for the season it was assumed that corn cultivation would be accomplished from June 3 to 26 and bean cultivation from June 21 to July 9 with 15.3 good work days for corn and 12.6 good work days for beans.

Table 3. — Combining Capacity in Acres

Row size	Per machine hour	Per season for corn[a]	Per season for beans[b]
2–40 in.	1.56	310.8	
3–30 in.	1.75	350.8	
3–40 in.	2.33	466.2	
4–30 in.	2.33	466.2	
4–40 in.	3.10	619.4	
6–30 in.	3.50	699.3	
10-ft. platform, 30-in. rows	2.33		176.4
10-ft. platform, 40-in. rows	2.33		176.4
13-ft. platform, 30-in. rows	2.92		220.9
13-ft. platform, 40-in. rows	3.10		234.4
16-ft. platform, 30-in. rows	3.50		264.6
16-ft. platform, 40-in. rows	3.89		294.0

[a] In determining the season's combining capacity for corn it is assumed there will be 22.2 good working days from October 11 to November 13.
[b] Combining for beans is in addition to that for corn. It is assumed there will be 8.4 good working days from September 20 to October 1.

Variable Costs

Per-acre variable costs are calculated using the hourly acreage capacities for the various machines given in Tables 2 and 3.

Repair costs were calculated in the following way:

$$R = P(TR/L)T \; ; \tag{3}$$

where: R = the repair cost per acre,
P = purchase price of the machine,
TR = total expected repair cost for the life of the machine as a fraction of purchase price,
L = expected life of the machine in hours, and
T = time in hours required for each acre of machine work.

Total repair cost fractions of purchase price used are as follows: planter, 30 percent, cultivator, 40 percent, combine, 40 percent, and tractor, 60 percent. Estimated life in hours is: planter, 1,200, cultivator, 2,500, combine, 2,000, and tractor, 9,000. A proportionate share of repairs for the tractor was included with costs for planting and cultivating. Assuming the tractor would be available regardless of equipment choice, fixed charges for the tractor were not included.

Fuel costs are estimated for gasoline-powered equipment. Twenty cents per gallon is used. This is the approximate bulk delivery price before gas tax which is refunded. Fuel consumption rates are calculated by using the approximate horsepower requirements for the various field operations.[1]

Factors affecting the horsepower requirements include: weight of the chemicals, fertilizers, and seed used in the planting operation, the weight of the planter and number of rows being planted, variation in soil condition and its resistance to the planter runners; similar items with respect to cultivating; and (most important in combining) the number of rows combined. Taking account of these various factors, fuel consumption estimates are made in Table 4.

Costs of oil and grease were estimated to be 13 percent of fuel cost with oil at 10 and grease at 3 percent.

Labor cost was calculated at $2.00 per hour for both machine time and overhead labor time. This is a conservative figure for persons skilled in machine work but is reasonable for comparative purposes. Frequently labor cost is ignored in calculating machinery costs because in the short run labor may be considered a fixed cost on many farms. Since there are significant differences in labor requirements for different machinery complements and since the important advantage of larger machinery is its substitution for labor, labor cost is included to make comparisons between the various machinery complements more valid.

Table 4. — Fuel Consumption for Field Operations in Gallons per Hour

Row size	Gasoline consumption[a]	
	Planting	Cultivating
4–30 in.	3.95	4.94
4–40 in.	3.95	5.25
6–30 in.	4.70	5.88
6–40 in.	4.70	6.25
8–30 in.	5.55	6.94
8–40 in.	5.55	7.38
70-hp. combine, 10-ft. platform		*Gasoline consumption per hour*
2–40 in. corn		4.1
3–30 in. corn		4.7
3–40 in. soybeans		4.2
4–30 in. soybeans		4.7
85-hp. combine, 13-ft. platform		
3–30 or 40 in. corn		5.3
4–30 or 40 in. corn		6.0
4–40 in. soybeans		5.3
5–30 in. soybeans		5.8
105-hp. combine, 16-ft. platform		
4–30 or 40 in. corn		6.8
6–30 in. corn		8.2
5–40 in. soybeans		6.6
6–30 in. soybeans		7.1

[a] Diesel fuel consumption is approximately 72 percent of gasoline consumption, and propane consumption is approximately 130 percent of gasoline.

ACREAGE COSTS OF ALTERNATIVE MACHINERY COMPLEMENTS

Tables giving a complete listing of all costs for all the equipment investigated in this study are in the appendix. For purposes of analysis, these individual costs have been added together for specified sets of machinery that are the most relevant alternatives in the decision-making process.

Since the combine costs in all cases are the largest share of the total costs for any set required in planting, cultivating, and harvesting, the combine size, row width, and capacity were allowed to dictate the size and row width of the planting and cultivating equipment. In most cases, combining accounted for about 75 percent of the total machine costs in planting, cultivating, and harvesting. Six different machine complements or machine sets are used for comparison purposes. All six of these machine complements depend on the combine size. Three sizes of combines with 30-inch row widths and three sizes of combines with 40-inch row widths are selected for comparative analysis:

1. The 3-row, 30-inch row width combine with approximately 70 horsepower has a season capacity of 350 acres of corn, and with the 10-foot platform it has an additional capacity of 176 acres of soybeans (Table 3). This means that because of available planting and cultivating equipment, the 6-row, 30-inch planter and cultivator are the optimum machines to go with the 3-row, 30-inch combine. This also means that compared with the combine, the planting and cultivating equipment required for this machine complement are about 50 percent oversized. Although this relatively poor fit in comparative machine capacity tends to increase cost for this set, it is better to have overcapacity in planting and cultivating compared with harvesting, because the planting and cultivating cost is a relatively small share of the total cost.

2. The 4-row, 30-inch row width combine requires the intermediate 85-horsepower machine. This combine has a season capacity of 466 acres of corn and an additional 220 acres of soybeans when using the 13-foot platform (Table 3). The planting and cultivating equipment required to round out this machine complement is the 8-row, 30-inch row width equipment. This also is substantially oversized. Four-row, 30-inch row width equipment is available. However, the capacity of this equipment would fall short of the combining capacity by about one-third. Using two sets of 4-row equipment would increase fixed costs and labor costs compared with the 8-row equipment. However, in some cases where several landlords are involved and each landlord wants his own land farmed first, duplication of smaller scale equipment may be necessary to hold several tracts of land. It should be clear, however, that when this is done, a large part of the cost advantage of large-scale farming is lost.

3. The 6-row, 30-inch row width combine is the largest size in the 105-horsepower range and has a season capacity of 699 acres of corn and an additional 264 acres of soybeans with the 16-foot platform. This combine requires two sets of the 6-row, 30-inch row width planting and cultivating equipment in order to have sufficient capacity to match the combine capacity. Corn-planting capacity with one planter would fall short by over 200 acres. This causes the cost curve to be discontinuous at the acreage level where the second set of planting and cultivating equipment is added.

4. The smallest size conventional-row combine is the 2-row machine with approximately 70 horsepower. This has a 310-acre corn capacity and an additional 176-acre soybean capacity with the 10-foot platform (Table 3). The planter and cultivator size needed to complement this size of combine is the 4-row, 40-inch row width equipment. So far as capacity is concerned, this size of planting and cultivating equipment is better than equipment in the machinery complement for the 3-row, 30-inch row width combine. In fact, this same comparison holds true for all sizes of machinery sets between the 30-inch row width and the 40-inch row width equipment.

5. The next larger size combine will handle 3 rows of the conventional row width and the 6-row planting and cultivating equipment in the conventional row width must be used to match the 3-row combine header. This size combine has a corn acreage capacity of 466 acres and 234 acres of soybeans with the 13-foot platform. The 6-row planter and cultivator have more than ample capacity for this machine.

6. The largest conventional-row combine corn head is the 4-row head. This head is sold to go on either the medium-size 85-horsepower combine or the large 105-horsepower combine. Some persons interviewed thought the smaller combine, however, often does not have the internal capacity or power to handle this size of corn head in the high-yielding corn. The costs for both sizes of combines with the 4-row head have been worked out. Over most of the range in acreage where one of these machines might be used, the cost difference in the two machines is approximately $2.00 per acre, caused mainly by the higher fixed cost of the larger machine. The larger machine also has a slightly higher per-acre operating cost. The larger machine is used in this analysis and the 8-row 40-inch planting and cultivating equipment is required to complete this machinery complement.

Production of All Corn

These six sets of machinery are the most logical machine complements, considering both physical requirements (row width, number of rows for compatible field operation, complementary acreage capacity) and economic requirements. Many machinery combinations are possible, but for practical reasons only these six sets of corn production machinery will be compared.

There are a number of farms in the central Corn Belt that are becoming specialized in growing only corn. On most other farms in the Corn Belt where soybeans and other crops are raised, corn is the dominant crop. Therefore, the cost relationships among the alternative machine complements are presented in this section with the assumption that nothing but corn is produced. This means that the additional investment cost and ensuing fixed-cost charges for a combine platform are not included. The basic combine with the average number of accessories and the corn head make up the fixed costs for the harvesting equipment in this analysis.

Table 5 gives the per-acre costs for the six sets of machinery complements at the various acreage levels that are relevant, given the physical capacity limitation of the different sets. Costs of combining are given separately from the total cost, which includes planting, cultivating, and combining. Combining costs are shown alone because this is the major cost and there may be several alternatives for some farmers other than owning the harvesting equipment. Some small farmers may be able to hire the harvesting done by a custom operator, or in some areas farmers may have the opportunity to rent a combine to harvest corn. Thus it is more important to know the cost of owning the equipment and doing this operation relative to the total machine cost.

NARROW VS. CONVENTIONAL ROWS

In comparing costs between 30-inch and 40-inch row width equipment, the sets given in Table 5 can be paired according to the upper limit of their physical capacity. Thus, set 1 can be compared with set 4, set 2 can be compared with set 5, and set 3 can be compared with set 6.

The Low-Capacity Complements

In comparing costs of the low-capacity pair of machinery complements (corn acreage below 300 to 350 acres), the 2-row, 40-inch row width equipment is from $2.00 to $6.00 an acre less expensive, depending on the acreage level used. If we consider the higher herbicide and insecticide cost that would ordinarily be required in narrow rows, then the difference would be still larger.

The average cost of herbicides applied in 12-inch to 14-inch bands on conventional-row corn is approximately $3.25 per acre; and the cost of insecticides with row treatment, also on conventional-row corn, is approximately $1.25 per acre. Using the same rates of application on narrow rows would result in a cost increase of one third. This means that

Table 5. — Per-Acre Costs for Machinery Complements in Production of All Corn

	Set 1 3–30-in. combine		Set 2 4–30-in. combine		Set 3 6–30-in. combine		Set 4 2–40-in. combine		Set 5 3–40-in. combine		Set 6[a] 4–40-in. combine	
	Combining only	Total including planting and cultivating	Combining only	Total including planting and cultivating	Combining only	Total including planting and cultivating	Combining only	Total including planting and cultivating	Combining only	Total including planting and cultivating	Combining only	Total including planting and cultivating
Annual fixed cost	2,145.06	2,496.32	2,264.37	2,776.66	2,739.54	3,090.53[b]	1,618.80	1,903.80	2,152.19	2,619.59	2,580.50	3,207.50
Per-acre variable cost	3.34	5.01	2.64	4.00	2.05	3.72	3.20	4.98	2.50	3.81	2.16	3.17
Per-acre cost at												
100 acres	24.79	29.97	25.28	31.75	29.44	34.62	19.38	24.01	24.02	30.00	27.96	35.24
150 acres	17.64	21.65	17.73	22.50	20.31	24.32	13.99	17.67	16.84	21.26	19.86	25.05
200 acres	14.06	17.48	13.96	17.87	15.74	19.16	11.29	14.49	13.26	16.90	15.06	19.20
250 acres	11.92	14.99	11.69	15.09	13.00	16.07	9.67	12.58	11.10	14.27	12.48	15.99
300 acres	10.49	13.33	10.18	13.24	11.16	14.00	8.59	11.32	9.67	12.53	10.76	13.86
350 acres	9.46	12.13	9.10	11.91	9.87	12.54	....	....	8.64	11.28	9.53	12.33
400 acres	....	....	8.30	10.93	8.89	11.43	....	....	7.88	10.35	8.61	11.18
450 acres	....	....	7.67	10.16	8.13	10.84	....	....	7.28	9.62	7.89	10.28
500 acres	....	....	7.16	9.53	7.52	9.88	....	....	6.80	9.04	7.32	9.57
550 acres	....	....	....	....	7.03	9.96	....	....	....	....	6.85	8.99
600 acres	....	....	....	....	6.61	9.45	....	....	....	....	6.46	8.51
650 acres	....	....	....	....	6.26	9.00	....	....	....	....	....	....
700 acres	....	....	....	....	5.96	8.63	....	....	....	....	....	....

[a] Figures used here are for the 105-horsepower combine. A 4-row head on the 85-horsepower combine will result in lower per-acre costs of less than $1.00 per acre in the acreage range where this size equipment would usually be used.

[b] Includes one 6-row planter and cultivator. An additional planter and cultivator are needed at over 500 acres.

in addition to the difference in machinery cost, there will be a higher cost of $1.50 per acre for herbicides and insecticides on narrow-row corn. It is assumed that any cost difference in seed or fertilizer would pay for itself. Thus with narrow-row corn at the lowest capacity of the three capacity sizes considered, the cost difference would run from $3.50 to $7.50 per acre, depending on acreage size. Therefore it appears that more than a 3-bushel minimum increase would be needed to offset the additional cost of narrow-row corn compared with conventional-row corn.

On tenant-operated farms where the lease is a crop-share lease, part of the increase in yield would accrue to the landlord's return. Depending on what additional costs might be paid by the landlord, the yield increase necessary to pay for added costs might well be 6 bushels per acre or more before the tenant could afford to change to narrow rows. As indicated earlier, yield increases have been about 5 percent for narrow-row corn over conventional-row corn. This means since most tenants pay all of the machinery costs, there are likely to be alternative investments in the farm business that bring higher returns. This is especially true if the present set of conventional-row equipment used by the tenant has a number of years of expected useful life remaining.

The Medium-Capacity Complements

The 4-row, 30-inch row width combine and its complement and the 3-row, 40-inch row width combine and its machinery complement are the medium-capacity equipment sets handling up to 466 acres of corn. The difference in machine cost at this acreage level is much less comparing narrow-row with conventional-row equipment. The cost difference at the acreage levels from 300 to 466 acres or at the volume for which this machinery would be used is less than a dollar an acre. This, of course, does not include the additional herbicide and insecticide cost that would be required. Therefore at this level of production (300 to 500 acres of corn), it would appear that narrow-row production should be profitable for owner-operators, and it also may be profitable for tenant operators, depending again on age and usefulness of present equipment.

Other items to consider in changing to narrow-row corn include the apparent greater difficulty in weed control and whether anhydrous ammonia or other low-cost forms of nitrogen can be properly applied. Given the somewhat greater difficulty with weed control experienced by some farmers with narrow-row corn, the additional herbicide cost always should be included in budgeting the cost differences between conventional- and narrow-row corn. Anhydrous or liquid nitrogen is not so easily side-dressed on narrow-row corn as on conventional-row corn. This form of nitrogen could be applied as a part of seedbed preparation. However, this means an additional field operation at a rather critical time of the year when ground is being prepared and corn is being planted. Nitrogen might be applied in the fall, but this could result in rather high nitrogen losses on some soils.

The High-Capacity Complements

The largest harvesting equipment capacity used in this study is 6-row, 30-inch row width and 4-row, 40-inch row width. This equipment along with the machinery complement that is associated with it, has a capacity up to 699 acres of corn for the 6-row and up to 619 acres of corn for the 4-row equipment. Here again the cost difference favoring conventional-row equipment over the relevant range of acreage volume is less than a dollar an acre.

Consider first the limitations of narrow rows already discussed — nitrogen application, weed control, and age and usefulness of present equipment. Since the 6-row harvesting complement has a capacity of almost a hundred more acres of corn, the 6-row, 30-inch row width complement may be the best alternative for the operator with over 500 acres of corn.

SCALE OF PRODUCTION

With the large investment required in corn production machinery, particularly the harvesting equipment, the various alternative investment opportunities and ways to harvest corn for different acreage levels of production become more important. A farmer with relatively small corn acreage may be able to get his corn harvested without owning harvesting equipment. Many such farmers often will have other priorities for investments of this size that will pay a higher return.

In the central Corn Belt, it is usually possible to hire some corn-combining custom work done. Custom combining ranges from $8.00 to $12.00 an acre, including labor. If getting grain away from the machine or if other farm work has a priority, this also is a way to hire labor that otherwise might be difficult to obtain during the harvest season. Few farmers, however, are willing to rely completely on custom operators to get their corn harvested. They are willing to pay a premium in machine ownership to have better control over harvest timing and greater certainty that the crop will be harvested with little loss. Some farmers with small acreages might be well advised to offer a custom operator a per-acre premium or bonus if the corn was harvested by a certain date.

The costs in Table 5 for either machinery complement set 1 or set 4 show that on an economic basis a farmer with 200 acres or less of corn could not afford to own a combine if custom harvesting was available. These figures, ranging from $11.29 or more per acre for the 2-row, 40-inch row width combine for 200 acres or less, indicate that a farmer with less than 200 to 250 acres could offer a custom operator a bonus in order to assure himself of harvesting services rather than owning the equipment himself. This is especially true if the farmer has an internal discount rate on capital expenditures of more than 6 percent, the rate used in this analysis.

If a farmer's acreage is smaller than required to justify machine ownership, doing custom harvesting for others may, in some cases, justify owning a combine. However, prospective custom operators or farmers thinking of doing some custom work in addition to their own should be cautioned before taking the figures in Table 5 at face value. A field efficiency ratio of 70 percent for combining was used in determining the cost figures in Table 5. Problems with custom work include: lost time in getting in and out of fields; small or irregularly shaped fields that cause lost time; and travel between jobs when doing one's own work. This lower efficiency (not accounted for in Table 5) will raise the combining costs that custom operators must expect to face and will decrease the acreage capacity of the various sizes of machines because of seasonal limitations.

In a few areas, it has been reported that machinery dealers are willing to rent combines to farmers. Depending on the rental arrangements (which often lead indirectly to ownership), it may be more desirable for a farm operator with corn acreage less than 250 acres to consider renting a machine for corn harvesting rather than owning a combine.

When is one of the larger machines more economical than the smallest capacity machine? By looking at the per-acre cost for the various acreage-capacity limitations of the various machine sizes given in Table 5, it is apparent that a general statement about the economics of machine size in corn production can be made: a machinery complement used at full capacity will generally be less costly per acre than a machinery complement of greater capacity used at the same level of production. Another way of stating this is: get the smallest capacity machinery complement that will handle the job.

There are a few cases where this general statement may not apply. It may be justifiable to own machinery when custom hiring would cost less but is not readily available, or to get larger capacity machinery than is now required if larger corn acreage is in view. A small owner-operator or a larger tenant-operator may justify such buying decisions on the assumption that he will be in a better position to attract or rent additional land. However, unless acquisition of additional land is definitely in view, this sort of justification of overcapacity equipment can lead to a long-term, high-cost operation that is really a risk cost taken in anticipation of farm enlargement.

Production of Corn and Soybeans

Because of seasonal limitations and because almost all corn production machinery is interchangeable for soybean production, greater machine use and lower overall fixed costs may result from adding soybean production to corn production. Because of seasonal limitations, the additional capacity of machine complements for soybean production on the average is about one-half as much as the corn acreage capacity (Tables 2 and 3). This means that corn and soybean production in the ratio of 2:1 would fully use the relative capacity of the various sizes of machine complements. Therefore the costs presented in Table 6 are calculated on the assumption of a 2:1 ratio of corn to soybeans and the per-acre costs are the average costs for both corn and soybeans. The basic cost data for the various machines for soybean production are given in the Appendix.

The per-acre costs given in Table 6 are the average for the total acreage of both corn and soybeans. Since using the machinery complement for both corn and soybeans substantially increases the capacity of each machine set, the per-acre costs at full-capacity use are substantially lower than the per-acre costs shown at full capacity use in Table 5 when only corn production is assumed. Here again it can be said that at any particular level of production, the per-acre cost of production will be least when the machinery complement used is the one having the smallest capacity that will handle that particular level of output.

The production cost differences between narrow-row and conventional-row complements at full-capacity use are only fifty cents an acre on the small-capacity set, a dollar an acre on the medium-capacity set, and $1.25 an acre on the large-capacity set. This takes into account only the machinery and labor costs. Additional required cost for herbicides and insecticides is approximately $1.50 per acre for corn. Additional costs for herbicides on soybeans and additional seed cost for narrow-row culture are approximately $2.33 per acre. This is $1.50 additional for herbicides and 83 cents for additional seed with soybean seed at $3.00 per bushel.

With an estimated increase of 10 percent or, in some cases, up to 15 percent in soybean yield, it is clear that narrow-row soybean production is more profitable than conventional-row production. In the case of a tenant who furnishes most of the additional costs but shares in the added return, the increase from narrow rows on soybeans is still sufficiently great to be profitable. Narrow-row soybeans appear sufficiently profitable that even if the additional return for narrow-row corn only pays for the additional cost, it would be profitable to use narrow-row culture if the capacity levels for soybeans indicated in Table 3 were maintained along with corn

Table 6. — Per-Acre Costs for Machinery Complements in Production of Corn and Soybeans[a]

	Set 1 3–30-in. combine		Set 2 4–30-in. combine		Set 3 6–30-in. combine		Set 4 2–40-in. combine		Set 5 3–40-in. combine		Set 6 4–40-in. combine	
	Combining only	Total including planting and cultivating	Combining only	Total including planting and cultivating	Combining only	Total including planting and cultivating	Combining only	Total including planting and cultivating	Combining only	Total including planting and cultivating	Combining only	Total including planting and cultivating
Fixed cost for corn	1,462.47	1,696.65	1,795.11	1,969.44	2,180.53	2,414.71	1,229.94	1,419.94	1,682.93	1,994.53	2,021.49	2,439.49
Fixed cost for beans	575.23	692.31	700.01	787.17	843.00	960.08	575.23	670.23	700.01	855.81	843.00	1,052.00
Total fixed cost	2,037.70	2,388.96	2,495.12	2,756.61	3,023.53	3,374.79[b]	1,805.17	2,090.17	2,382.94	2,850.34	2,864.49	3,491.49
Per-acre variable cost for corn	3.07	4.72	2.64	4.98	2.05	3.72	3.20	4.98	2.50	3.81	2.16	3.17
Per-acre variable cost for beans	2.11	3.78	1.90	4.24	1.78	3.45	2.07	3.85	1.75	3.05	1.57	2.58
Per-acre combined variable cost	2.75	4.42	2.39	4.73	1.96	3.63	2.82	4.60	2.25	3.56	1.63	2.64
Acres of corn and beans												
150	16.33	20.35	19.04	23.14	22.13	26.12	14.87	18.56	18.15	22.61	20.73	25.93
225	11.80	15.04	13.49	17.00	15.41	18.63	10.86	13.91	12.85	16.26	14.37	18.17
300	9.54	12.40	10.71	13.93	12.04	14.88	8.85	11.58	10.20	13.10	11.18	14.29
375	8.19	10.80	9.05	12.09	10.03	12.63	7.64	10.19	8.61	11.18	9.27	11.94
450	7.28	9.74	7.94	10.87	8.68	11.13	6.84	9.26	7.55	9.91	8.00	10.40
525	6.64	8.98	7.15	9.99	7.72	10.06	....	....	6.79	9.00	7.09	9.30
600	....	....	6.55	9.33	7.00	9.25	....	....	6.27	8.32	6.41	8.46
675	....	....	6.09	8.82	6.44	8.63	....	....	5.75	7.79	5.88	7.78
750	....	....	....	....	5.99	8.60	....	....	....	....	5.45	7.30
825	....	....	....	....	5.63	8.15	....	....	....	....	5.10	6.88
900	....	....	....	....	5.32	7.77	....	....	....	....	4.81	6.52
975	....	....	....	....	5.06	7.45	....	....	....	....	4.57	6.22
1,050	....	....	....	....	4.84	7.18	....	....	....	....	....	....

[a] Assuming a corn-to-soybeans acreage ratio of 2:1.
[b] Includes only one 6-row planter and cultivator. An additional planter and cultivator will be needed at over 750 acres.

production. Of course, before any change is made, the individual situation must be considered. Since capital availability is limited at some level on all farms, there may be other higher paying priorities for capital investment that should be handled before change to narrow-row production can be considered. Also, some farmers recently have purchased new equipment, so an individual farmer may be unable to make the change until present equipment has received more use.

CRITERIA FOR TIME TO TRADE MACHINERY

The foregoing material is useful to farm operators, prospective farm operators, and custom machinery operators in order to compare various alternative investments in corn production machinery complements. Before farm operators can decide when to trade existing machinery for new machinery, they need some additional criteria.

A number of research and extension workers have worked out methods to calculate when to trade machinery. Some of these methods are fairly complex.

If we refer to economic theory (see Scott, p. 44, and Lutz, p. 106) we can extract some economic principles and integrate these into a fairly simple statement or guide on when to trade: The time to trade is when the annual operating cost of old equipment is greater than the expected average annual total cost of the new equipment.

Two things are included in the cost of old equipment. These are (1) the actual operating cost — gas, oil, labor, and repairs, and (2) the cost of any additional gain in gross return lost because of the older technology of the old equipment — such as the difference in yield from narrow rows. It is inherently assumed that the operating costs of the old equipment will get larger rather than smaller as time goes on.

The average annual total cost of new equipment includes the expected average operating cost and the expected average net fixed cost. By net fixed cost is meant the fixed cost figured on the difference needed to trade when the value of old equipment traded in and any additional bargaining reduces the list price of the new equipment. A farmer knows the operating cost of his present machinery from his existing records. The previous discussion and the appendix will give good indications of the operating and fixed costs on the various alternative sets of new equipment in corn production.

There are times when other criteria may be the deciding factor. For example, if an operator substantially enlarges his farming operation by either buying or renting additional land, he may find it necessary to purchase new machinery that has greater capacity to get the job done.

SUMMARY

This study compares the costs of six sets or machinery complements available for corn and soybean production. These six sets cover the range of scale of operation and they make it possible to compare the differences between conventional- and narrow-row culture. Two general cost comparisons were made — one assuming production of nothing but corn, and the other assuming a 2:1 acreage ratio of corn and soybean production. A detailed breakdown of the basic cost data for all individual items of machinery considered in the study is given in the appendix for those interested in specific cost items. Consideration in the study is given to scale of operation (including custom hiring and renting of machinery), to costs and other criteria for choosing between narrow and conventional rows, and to criteria for when to trade in old machinery.

So far as size of machinery is concerned, a general rule that usually is applicable is to obtain the smallest capacity machinery complement that is just adequate to do the job.

Where nothing but corn is produced, narrow rows are questionable, especially when the farm operator is a tenant on a crop-share lease receiving only a part of the increased return or when other investment opportunities may have a higher priority. Where both corn and soybeans are produced, narrow-row culture is likely to be profitable.

The general rule on trading is to trade when the annual operating cost of old equipment is greater than the expected average annual total cost of the new equipment.

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APPENDIX

Table 1. — Fixed and Variable Costs for Planting

	Planting costs					
	4–30 in.	4–40 in.	6–30 in.	6–40 in.	8–30 in.	8–40 in.
Annual fixed costs						
Depreciation	108.00	108.00	144.00	180.00	222.75	252.00
Interest	36.00	36.00	48.00	60.00	74.25	84.00
Taxes	12.00	12.00	16.00	20.00	24.75	28.00
Shelter	12.00	12.00	16.00	20.00	24.75	28.00
Insurance	3.00	3.00	4.00	5.00	6.19	7.00
Total	171.00	171.00	228.00	285.00	352.69	399.00
Variable costs per acre						
Repairs (planter)	.08	.06	.07	.07	.09	.07
Fuel	.22	.16	.17	.13	.15	.11
Oil and grease	.03	.02	.02	.02	.02	.01
Repairs (tractor)	.11	.08	.07	.05	.05	.04
Labor	.64	.48	.43	.32	.32	.22
Total	1.08	.80	.76	.59	.63	.45

Table 2. — Fixed and Variable Costs for Cultivating

	Cultivating costs					
	4–30 in.	4–40 in.	6–30 in.	6–40 in.	8–30 in.	8–40 in.
Annual fixed costs						
Depreciation	57.15	72.00	77.85	115.20	100.80	144.00
Interest	19.05	24.00	25.95	38.40	33.60	48.00
Taxes	6.35	8.00	8.65	12.80	11.20	16.00
Shelter	6.35	8.00	8.65	12.80	11.20	16.00
Insurance	1.59	2.00	2.16	3.20	2.80	4.00
Total	90.49	114.00	123.26	182.40	159.60	228.00
Variable costs per acre						
Repairs (cultivator)	.03	.03	.03	.04	.03	.03
Fuel	.34	.27	.27	.22	.24	.19
Oil and grease	.04	.04	.04	.03	.03	.02
Repairs (tractor)	.13	.10	.09	.07	.07	.05
Labor	.72	.54	.48	.36	.36	.27
Total	1.26	.98	.91	.72	.73	.56

Table 3. — Variable Costs per Acre for Combining Corn and Soybeans

	Corn								
	70 hp. 2–40 in.	70 hp. 3–30 in.	85 hp. 3–40 in.	85 hp. 3–30 in.	85 hp. 4–40 in.	85 hp. 4–30 in.	105 hp. 4–40 in.	105 hp. 4–30 in.	105 hp. 6–30 in.
Repairs	1.17	1.19	1.04	1.38	.83	1.10	.94	1.26	.88
Fuel	.53	.54	.45	.61	.39	.52	.44	.58	.47
Oil and grease	.07	.07	.06	.08	.05	.07	.06	.08	.06
Labor	1.43	1.27	.95	1.27	.72	.95	.72	.95	.64
Total	3.20	3.07	2.50	3.34	1.99	2.64	2.16	2.87	2.05

	Soybeans					
	70 hp. 3–40 in.	70 hp. 4–30 in.	85 hp. 4–40 in.	85 hp. 5–30 in.	105 hp. 5–40 in.	105 hp. 6–30 in.
Repairs	.71	.71	.65	.69	.62	.69
Fuel	.36	.40	.34	.40	.34	.41
Oil and grease	.05	.05	.04	.05	.04	.05
Labor	.95	.95	.72	.76	.57	.63
Total	2.07	2.11	1.75	1.90	1.57	1.78

Table 4. — Fixed Costs of Combining, Assuming All Corn

Fixed costs	70 hp. 2–40 in.	70 hp. 3–30 in.	85 hp. 3–40 in.	85 hp. 3–30 in.	85 hp. 4–40 in.	85 hp. 4–30 in.	105 hp. 4–40 in.	105 hp. 4–30 in.	105 hp. 6–30 in.
Depreciation	1,140.00	1,303.75	1,515.63	1,510.63	1,604.63	1,594.63	1,817.25	1,833.25	1,929.25
Interest	273.60	312.90	363.75	362.55	385.11	382.71	436.14	439.98	463.02
Taxes	91.20	104.30	121.25	120.85	128.37	127.57	145.38	146.66	154.34
Shelter	91.20	104.30	121.25	120.85	128.37	127.57	145.38	146.66	154.34
Insurance	22.80	26.08	30.31	30.21	32.09	31.89	36.35	36.67	38.59
Total	1,618.80	1,851.33	2,152.19	2,145.09	2,278.57	2,264.37	2,580.50	2,603.22	2,739.54

Table 5. — Fixed Costs of Combining, Assuming a 2:1 Acreage Ratio of Corn to Soybeans

	Fixed costs on corn								
	70 hp. 2–40 in.	70 hp. 3–30 in.	85 hp. 3–40 in.	85 hp. 3–30 in.	85 hp. 4–40 in.	85 hp. 4–30 in.	105 hp. 4–40 in.	105 hp. 4–30 in.	105 hp. 6–30 in.
Depreciation	866.16	1,029.91	1,185.17	1,180.17	1,274.17	1,264.17	1,423.58	1,439.58	1,535.58
Interest	207.88	247.18	284.44	283.24	305.80	303.40	341.66	345.50	368.54
Taxes	69.29	82.39	94.81	94.41	101.93	101.13	113.89	115.17	122.85
Shelter	69.29	82.39	94.81	94.41	101.93	101.13	113.89	115.17	122.85
Insurance	17.32	20.60	23.70	23.60	25.48	25.28	28.47	28.79	30.71
Total	1,229.94	1,462.47	1,682.93	1,675.83	1,809.31	1,795.11	2,021.49	2,044.21	2,180.53

	Fixed costs on soybeans		
	70 hp. 10-ft. platform	85 hp. 13-ft. platform	105 hp. 16-ft. platform
Depreciation	405.09	492.96	593.67
Interest	97.22	118.31	142.48
Taxes	32.41	39.44	47.49
Shelter	32.41	39.44	47.49
Insurance	8.10	9.86	11.87
Total	575.23	700.01	843.00

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